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The Construction and Application of an Aledo-NDVI Based Desertification Monitoring Model

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Abstract

A desertification monitoring model was constructed and applied in a region nearby Gaotai Country, China, where undergoing a typical desertification process. First, the surface albedo and vegetation index were retrieved. And by statistical regression analysis, the quantitative relationship between albedo and NDVI of different desertification land was determined, and found they have good correlation with the coefficient 0.7707. Based on this, the model of desertification monitoring was constructed; then, using decision tree to classify the desertified land and evaluate the quantitative relationship of them by natural breaks method; finally, Quick Bird image was used to test the classifying results and the overall accuracy of the model reaches 84.071%. The study shows that the indexes of the model can reflect the desertification land surface cover, the water-heat combination and their changes. It can make full use of multi-dimensional remote sensing information and can achieve the automatic identification of desertified land.

Keywords: Albedo, NDVI, Monitoring Model, Desertification.

1. Introduction

China is one of the most serious countries affected by desertification in the world [1]. Scientific and accurate data about the status of desertification can provide important basis for both desertification research and control. Early in the 20th century 70's, remote sensing satellite was used on desertification monitoring [2]. With the rapid development of remote sensing technology, its use on desertification monitoring is also matured. NDVI and LST, MSDI, the spectrum mixed analysis (SMA) were used to

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analysis ecological system of sandy land (Dall'Olmo G et al. 2002)[3], ecological system degradation of semiarid areas(Tanser et al. 1999)[4], desertified land monitoring(Alfredo et al. 2002)[5], respectively. Sandy land and barren land were separated by linear spectral mixture model (LSMM) in arid areas (Zhang Xichuan et al. 1999) [6]. Desertification and remote sensing information extraction with vegetation index and albedo were studied (Zeng YongNian, Pan Jinghu et al. 2006, 2010) [7, 8]. This study will construct the desertification monitoring model and propose a method for quantitative monitoring of desertification by using Landsat TM image, so as to provide a good monitoring of desertification model with remote sensed data.

2. Study area and data processing

2.1. dy area

Gaotai County is located in the lower segment of Heihe River middle reaches, south of the Badain Jaran Desert, and it is approximately between latitude 39°3′50″N-39°59′52″N, longitude 98°57′27″E-100°6′42″E, with the altitude between 1260m and 3140m, which belonged to the temperate continental climate with an average annual precipitation is 110.4 mm, annual evaporation is 1923.4 mm, and the annual average temperature of 7.8℃-8℃. The surface soil layer is dry, and the aridity reaches 5.5. The selected research area is near the central of Gaotai County, where a typical desertification process with complete types is undergoing.

2.2. Data sources and pre-processing

Two TM images of Landsat 5 covering the whole study area acquired on September, 11, 2006 and the track number with 133/033 and 134/032 were selected as the basis information source.

Radiometric correction and geometrical correction was done firstly. Radiometric correction includes radiometric calibration and atmospheric correction two steps; the former can eliminate the error caused by the sensor itself, and the purpose of the latter is to eliminate the error caused by atmospheric scattering and absorption, which was done by using quick atmospheric correction under the support of ENVI4.7 software. Polynomial method is adopted in geometrical correction, and the rectification error is kept below half a pixel. On this basis, the DN value of images was converted into radiance which was then used to convert into Albedo.

2.3. Parameters of remote sensing calculation

Calculation of normalized difference vegetation index (NDVI): NDVI is based on the equation (1):

$$NDVI = \frac{\rho_{\mathrm{nir}} - \rho_{\mathrm{red}}}{\rho_{\mathrm{nir}} + \rho_{\mathrm{red}}} \qquad (1)$$

Where ρ_{nir} and ρ_{red} represent the reflectance of near-infrared band and red band respectively.

Calculation of land surface albedo: albedo is calculated by using the formulate (2) established by Liang [9]:

$$Albedo = 0.356\rho_{TM1} + 0.130\rho_{TM3} + 0.373\rho_{TM4} + 0.085\rho_{TM5} + 0.072\rho_{TM7} - 0.0018 \qquad (2)$$

Where, ρ_{TMn} is the reflectance of the image's band n.

Data normalization processing: find out the maximum and minimum value of NDVI and albedo on study area, and then use them for data normalization processing.

$$N = \frac{NDVI - NDVI_{\min}}{NDVI_{\max} - NDVI_{\min}} \times 100\% \quad (3)$$

$$A = \frac{Albedo - Albedo_{\min}}{Albedo_{\max} - Albedo_{\min}} \times 100\% \quad (4)$$

3. Characterization of desertification on Albedo-NDVI feature space

Desertification is a form of land degradation in arid, semi-arid and dry sub-humid areas due to climate change, human activities and many other kinds of factors [10]. Many indexes were used for evaluation of desertification, among them, the area of sand land and vegetation coverage are the most simple and practical indexes. Using RS technology to acquire these two indexes would need to analyze their spectral characteristics and determine their quantitative relationship with desertification.

Albedo is a physical parameter affected by land surface conditions, such as soil moisture, vegetation coverage, snow and so on. By studying on location observation data, Li et al. [11] found that with the aggravation of desertification degree, the surface conditions changed obviously, not only decline in vegetation coverage and roughness, surface water also is correspondingly reduced, and albedo is increased. Therefore, albedo can be used as an important physical parameter reflecting land desertification.

Vegetation index is a dimensionless, radiometric measure that indicates relative abundance and activity of green vegetation [12]. DNVI is currently the most widely used vegetation index, which can effectively monitor vegetation coverage and estimate leaf area index, so it is also selected as a parameter reflecting land desertification.

The above analysis shows that there is significant correlation between the process of desertification and DNVI, albedo. Zeng Yongnian et al. [7] summarized the situation of desertification under different vegetation coverage based on NDVI and Albedo feature space (Fig.1). With the reduction of vegetation coverage, albedo increases correspondingly, and the changes of albedo will affect the surface radiation balance, thereby affect land surface temperature. In Albedo-NDVI feature space, albedo is not only a function of vegetation coverage but also a function of soil moisture content. AC side of figure 1 represents high albedo line and reflects the drought situation, which is the limit of high albedo corresponding to the complete arid land under certain vegetation coverage; and BD side is the low albedo line, representing the surface water is sufficient.

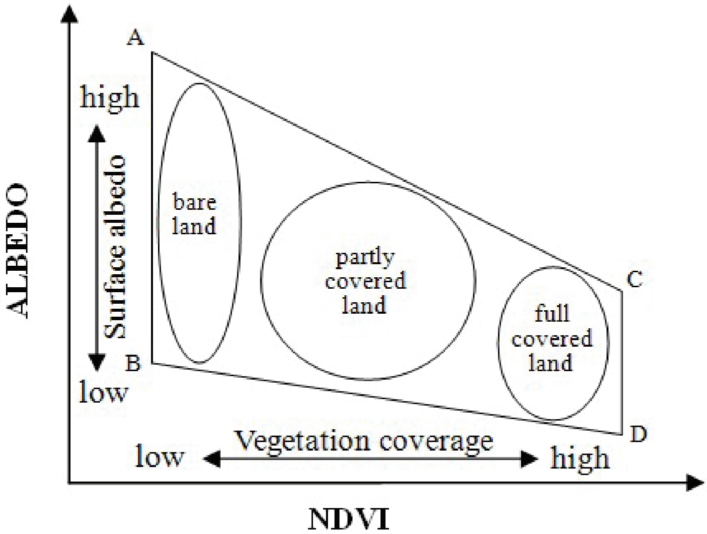

Fig. 1 Albedo-NDVI feature space

Albedo-NDVI feature space shows that: with the severity of desertification increased, vegetation coverage reduced, surface energy and water balance changed, resulting in a corresponding reduction of soil moisture and increase in albedo. Therefore, the combination information of albedo and NDVI can be used to distinguish different desertification lands effectively, in order to achieve quantitative monitoring and research on distribution and dynamic changes on desertification land. This requires a comprehensive index by some to divide the Albedo-NDVI feature space.

4. Model construction and application

In order to further the study of spatial distribution law of desertification in Albedo-NDVI feature space, we draw scatterplot chart for different desertification land cover types, based on regularization processed data. And then, we find different desertification lands can be separated easily in the feather space. We generate 500 points randomly in the study area by using create random points tool in ArcGIS9.3, and extract albedo, NDVI of each point correspondingly. After statistical regression analysis of these 500 sample points, we find albedo and NDVI have significant negative linear correlation. The regression equation is:

$$Albedo = 136.35 - 1.197 NDVI \qquad (5)$$

The correlation coefficient reaches a number of 0.7707. This indicates that with the increase of desertification, NDVI decreases gradually, while albedo increases. And in the Albedo-NDVI feature space, the process of desertification has been reflected clearly.

According to the study of Verstraete and Pinty's [13], different desertification lands can be effectively separated by dividing Albedo-NDVI feature space in the vertical direction of changing trends of desertification (Fig. 2). And the location of vertical direction in Albedo-NDVI feature space can be well fitted by a simple binary linear polynomial expression:

$$I = a \cdot NDVI - Albedo \qquad (6)$$

Where, "I" is called desertification divided index, "a" is determined by the slope of expression (5) and in this paper it's 0.893096. On this basis, we divide the value of "I" into five different levels with the method of natural breaks (Jenks). These five levels represent the different desertification land cover types as followed: non-desertification land (water body and vegetation covered land), weak desertification land, moderate desertification land, serious desertification land and extremely serious desertification land (the NDVI and Albedo of water are both very low, the relationship between them doesn't meet expression five, therefore the “I” values of water body distribute more widely). The natural breaks method uses the statistical Jenks optimization to get the demarcation point, which can make the internal variance of each category reach a minimum.

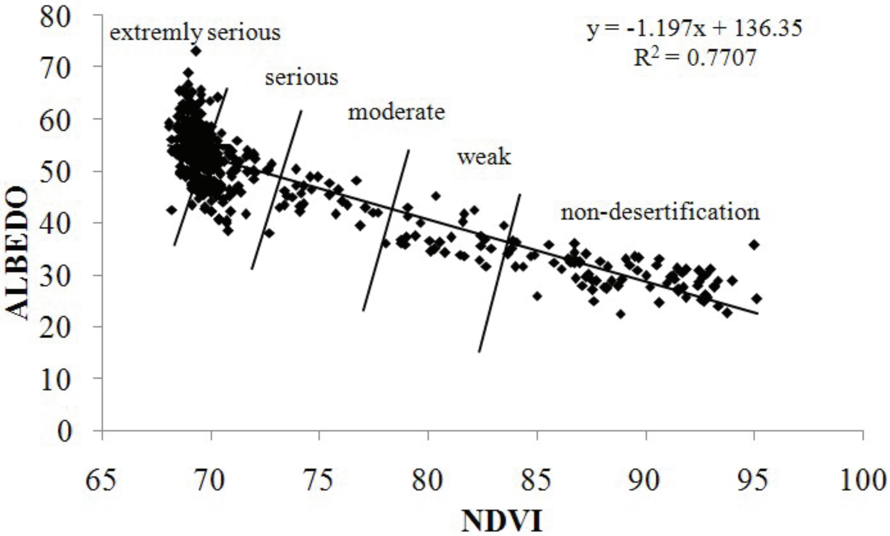

Fig. 2 Graphical representation of desertification in Albedo-NDVI space

According to desertification divided index, we use the decision tree classification method to classify desertification land of study area. The “I” values of different desertification lands and results of desertification land evaluation can be found in table 1, and fig.3 is the desertification evaluation results map.

Table 1 the “I” values and results of desertification land evaluation

Type of desertification	I Value	Number of pixels	Area [km^2]	Percentage of total area [%]
non-desertification land (vegetation covered land)	>32.74	550783	495.7047	16.3924
non-desertification land (water body)	-	19488	17.5032	0.5788
weak desertification land	27.00-32.74	125016	112.5144	3.7207
moderate desertification land	16.42-27.00	897631	807.8679	26.7152
serious desertification land	8.45-16.42	1015720	914.148	30.2298
extremly serious desertification land	<8.45	751362	676.2258	22.362

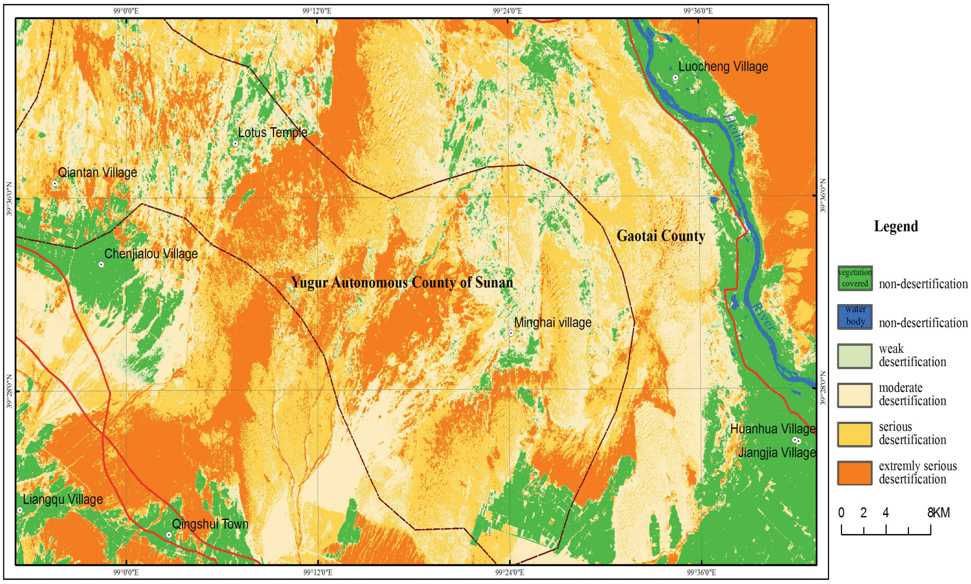

Fig.3 Evaluation result of desertification monitoring model

Finally, we use Quick Bird remote sensing satellite images to test the evaluation results, and find that the overall accuracy is more than 84.071%. Among them, the accuracy of non-desertification is 97.403%, weak desertification's accuracy is 84.375% and moderate desertification's accuracy is 85.388%, the accuracy of serious desertification and extremely serious desertification are 84.071% and 84.615% respectively.

5. Conclusions

In this article, we proposed a desertification monitoring model based on the relationship between desertification and a two indexes such as albedo, NDVI, as well as the spatial distribution law of desertification in Albedo-NDVI feature space. Then the model was applied in study area with relatively complete desertification types in the middle reaches of Heihe River.

The results show that: (1) the indexes of the model can reflect the desertification land surface cover, the water-heat combination and their changes, and it also has definite biophysical significance; (2) the model can make full use of easy accessed multi-dimensional remote sensing information, and has higher monitoring accuracy; (3) it can easily achieve the automatic identification of land desertification quantitatively, and is a quick and efficient method for desertification monitoring.

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